UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/752,416	01/06/2004	David G. Mikolas	100116	3899

29050 7590 09/22/2005

STEVEN WESEMAN
ASSOCIATE GENERAL COUNSEL, I.P.
CABOT MICROELECTRONICS COPORATION
870 NORTH COMMONS DRIVE
AURORA, IL 60504

EXAMINER	
NGUYEN, GEORGE BINH MINH	
ART UNIT	**PAPER NUMBER**
3723	

DATE MAILED: 09/22/2005

Please find below and/or attached an Office communication concerning this application or proceeding.

e

Office Action Summary	Application No.	Applicant(s)
	10/752,416	MIKOLAS ET AL.
	Examiner	Art Unit
	George Nguyen	3723

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *09 August 2005*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-12 and 14-18* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-12 and 14-18* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

'DETAILED ACTION

Receipt is acknowledged of Applicant's amendment filed on August 09, 2005.

Claim 13 was canceled. Claims 1-12 and 14-18 are presented for examination.

Continued Examination Under 37 CFR 1.114

1. A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after final rejection. Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, the finality of the previous Office action has been withdrawn pursuant to 37 CFR 1.114. Applicant's submission filed on August 09, 2005 has been entered.

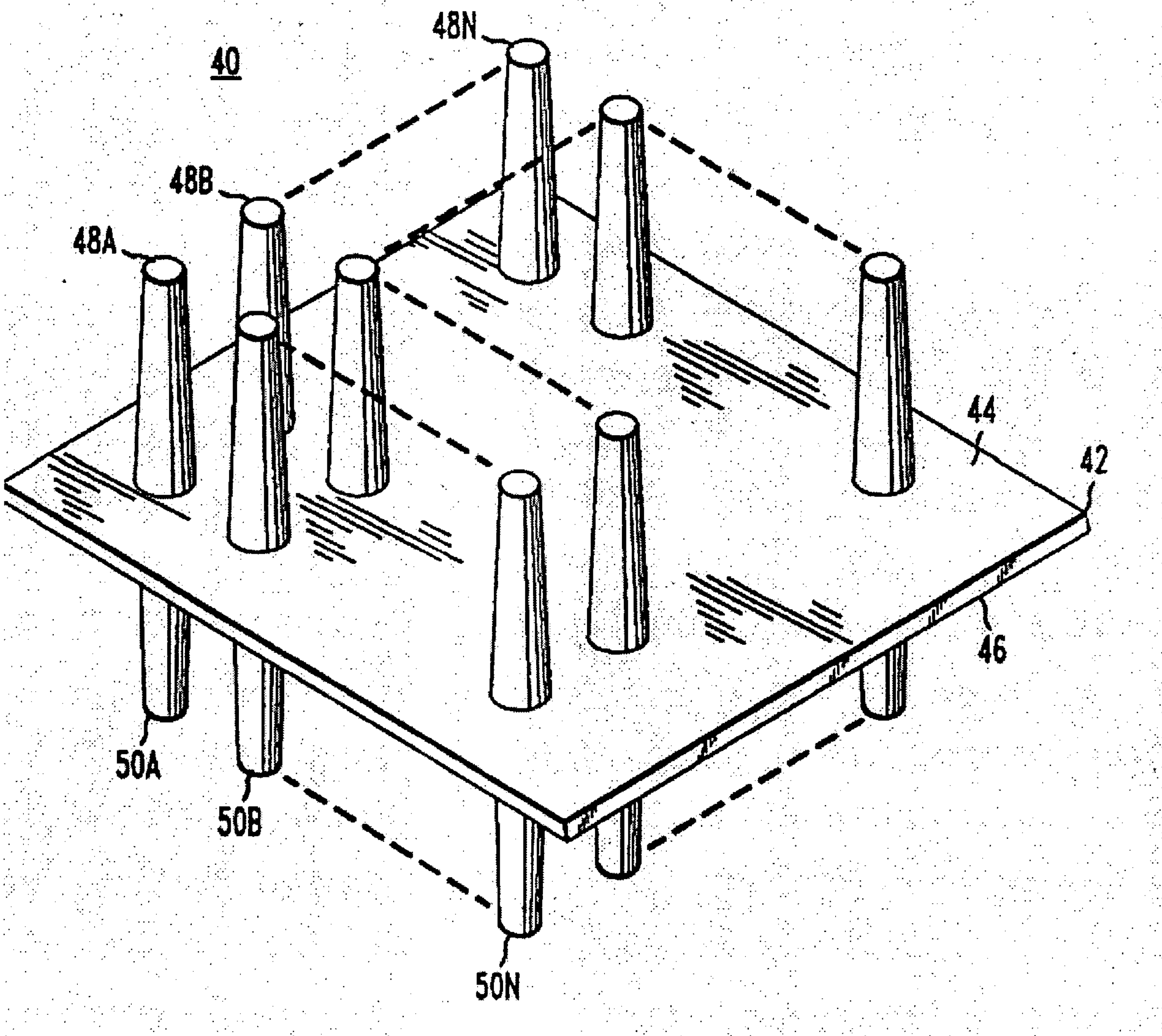
Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

3. Claims 1-12 and 14-18 are rejected under 35 U.S.C. 103(a) as being unpatentable over Goossen et al.'5,170,455 in view of Hawkins et al.'5,711,890. With reference to Figure 3, col. 2, line 48 to col. 4, line 65, Goosen discloses the claimed invention except for the micromachining being chemical mechanical polishing. Please note that in col. 3, lines 4-6, Goossen suggested that the pillars can be formed by micromachining using chemical etching ***<u>or the like.</u>***

FIG. 3



OPTICAL CONNECTIVE DEVICE

TECHNICAL FIELD

This invention relates generally to an optical connective device, and more particularly, to a monolithic array of optical fibers.

BACKGROUND OF THE INVENTION

Currently, optical fibers are used in optical backplanes for computers where the distances being traversed is only tens of centimeters. The use of optical fibers allows for higher bandwidth operation because skin effect losses associated with metal conductors is avoided. Thus, it is becoming attractive to develop equipment such as computers and the like in which direct chip-to-chip or board-to-board connections via light is used. In addition to the high speed, low attenuation and higher bandwidth possible per channel with an optical connective device, interference due to electromagnetic energy is eliminated.

Two current optical connective devices which have been developed are identified in publications as the Columbia University design and the Honeywell design. In the Columbia University design a single mode optical fiber is coupled to a buried detector via a carefully machined aluminum guide coupled to a side of a chip. In the Honeywell design, an array of optical fibers are arranged along a single plane and held in alignment via a chemically machined silicon V-groove fixture. The ends of the optical fibers are positioned over detectors in a chip, the ends being beveled to direct light from the optical fibers to the detectors.

The cores of optical fibers are very fine, their core diameter being less than 15 microns. Obviously, therefore, the manufacture of current optical connective devices which requires positioning an end of an optical fiber into a slot or an opening to obtain alignment with a detector or an optical path on a chip or a board not only required great accuracy, but is usually difficult and painstaking.

Clearly, a need exists for an optical connect for chips and boards which is economical to construct, has dimensions which are dependably accurate, and which permits chips and boards to be more closely coupled to each other.

This invention is directed toward an optical connective device which meets these needs.

SUMMARY OF THE INVENTION

This invention is an optical connective device which can have a two-dimensional array of optical fibers. The device can be comprised of a single piece of light conducting material such as glass, plastic or the like shaped to have a slab support member having pillars which project outward from opposing surfaces. The pillars on one of the opposing surfaces are optically aligned with corresponding pillars on the other opposing surface. The length of a pillar can be as small as its diameter. The ends of the pillars can be flat or curved to form a lens and each pillar can be accurately located to an arbitrary position. The optical connective device can be sandwiched between chips to provide an integrated circuit chip-to-chip connective device for a stack of two or more chips.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic of a prior art single fiber connect usually identified as the Columbia University design;

FIG. 2 is a schematic of a prior art single plane array optical fiber connect usually identified as the Honeywell design;

FIG. 3 is a schematic of structure in accordance with the principles of the invention of a two plane array optical fiber connect; and

FIG. 4 is an enlarged view of a section of the structure of FIG. 3.

DETAILED DESCRIPTION

The drawings are not necessarily to scale and certain parts of the drawing have been simplified to aid in clarity of exposition.

Referring to FIG. 1, there is illustrated the prior art Columbia University design. In this structure, the cladding 10 at the end of a single mode optical fiber 12 is removed to expose the core 14. The exposed core of the fiber is inserted through an opening 16 in a precision machined aluminum guide 18 which is coupled securely via epoxy cement or the like to a chip 20. The exposed end of the fiber projects into an opening 22 of the chip for coupling to, for example, a buried detector. The single mode optical fiber 12 is secured to the aluminum guide 18 with an adhesive such as epoxy cement.

FIG. 2 illustrates the prior art Honeywell design. In this structure, an alignment fixture 30 contains a plurality of chemically machined grooves 32, each being adapted to receive and hold an optical fiber 34. The ends 36 of the optical fibers are held captive by the grooves which are beveled to permit light in the core of a fiber to be reflected out at a desired angle. Obviously, if the bevel has an angle of 45°, the light will leave the fiber at an angle of 90° to the axis of the core. The Honeywell design can be used to couple an array of optical fibers aligned in a single plane to integrated detectors 38 located along a perimeter of a chip or a board.

Manufacture and assembly of each of the prior art optical fiber connects requires a highly skilled worker. They are expensive to construct, and are not practical for chip-to-chip coupling where it is desirable to have the chips closely stacked.

Referring to FIG. 3, there is illustrated structure 40 in accordance with the principles of this invention. In one embodiment of the invention, a support member 42 having opposing surfaces 44, 46 supports a first 48 and second 50 array of pillars. The first array of pillars consist of discrete pillars 48A, 48B, 48C . . . 48N; and the second array of pillars consist of discrete pillars 50A, 50B, 50C . . . 50N. The various pillars 48A . . . 48N which project outward from surface 44 are optically aligned with corresponding pillars 50A . . . 50N which project outward from opposing surface 52. Support member 42, pillars 48A . . . 48N and pillars 50A . . . N are monolithic, a structure of a common material which can transmit optical energy. Thus, optical energy received by any one pillar 48N which projects outward from surface 48 will be transmitted through that pillar 48N, through the portion of the support member 42 coupled to the end of the pillar 48N, and then through the pillar 50N optically aligned with the pillar 48N which received the optical energy. In this invention, the pillars operate as optical fibers where the lengths of

each optical fiber is the length of pillar 48N plus the length of pillar 50N plus the thickness of the support member 42.

In the embodiment of FIG. 3, the pillars can be formed by micromachining, using either a laser, ion milling, chemical etching, injection molding or the like. The term "micromachined" as used herein with respect to an array of pillars which project outward from opposing surfaces of a support member, is to be construed to mean a structure which is configured using any process which can produce the inventive structure with a high degree of dimensional and geometric accuracy. Materials which can be utilized to form the structure by etching includes, but is not limited to Fotoform™ glass (obtained from Corning Glass).

Fotoform material is photopatternable via exposure to UV light and subsequent chemical etching. Pillars having lengths of six hundred microns, diameters of less than forty microns and spacing of less than fifty microns can be achieved using this material. The processed glass is transparent and transmits optical energy.

More specifically, Fotoform material can be processed to form the inventive device by, first, exposing either one or both surfaces of a plate of Fotoform to ultraviolet (UV) light through a high precision mask. The mask forms a desired pattern of UV light on a ground and polished surface of a plate of Fotoform glass. The exposed plate is heat treated to develop the pattern. The areas of the glass that was exposed to the UV light becomes a semi-crystalline, glass-ceramic material that is 30 to 50 times more soluble in a dilute hydrofluoric acid solution than the nonexposed parts of the glass. This solubility differences enables the exposed pattern to be differentially etched.

More specifically, Fotoform has the property that when exposed to ultraviolet light (UV), silver atoms form crystallization centers in the exposed regions, which during a subsequent heat treatment allow nucleation and growth of lithium metasilicate crystals. Once this heat treatment is completed, the regions which were exposed to UV are 30-40 times more soluble in dilute hydrofluoric acid than unexposed regions. An optical connective device was formed by exposing a plate 1.6 mm thick to plane-wave UV normally incident through a standard photolithographic mask with small opaque disks. Upon heating to 600° C., the regions exposed to UV crystallize. The plate is then exposed to agitated HF causing fast etching of the crystallized regions from both faces leaving pillars. Slight etching of the non-UV-exposed regions occurs causing the pillars to have a 3° taper. Therefore, the base of the pillars have the same diameter as the mask disk (d_m), and the tip of the fiber has a diameter given by $d_t = d_m - 0.105 \times l$, where l is the pillar length. The etch was timed so as to leave a 170 μm thick supporting member. Thus, the pillars were each approximately 700 μm long. The resulting pillar tips were roughened by the etch, so mechanical polishing was performed. During polishing, the fibers were supported by wax that was melted and flowed between the fibers and allowed to cool. The entire fabrication process was performed with negligible variations across a 4×4 inch plate. If desired the end of the pillars can be shaped to have a lens rather than being flat. One method of producing a lens is to heat the ends of the pillars until the material starts to melt and form a convex shaped lens.

Pillars whose tips have a diameter of nominally 40, 60, 80 and 100 μm and arrays with center-to-center spacings of 400 and 1000 μm have been fabricated.

The inventive connect device can also be formed by using Lexan™ OQ-1020 from General Electric. This method is an optically transmitting plastic which, in combination with the injection molding process, forms a one-piece molded device. During the molding process, care should be exercised to insure that all bubbles have been eliminated from the finished product.

After the pillars have been formed on the support number, a wax-like material can be melted and poured onto each surface and allowed to solidify. This wax-like material provides mechanical support to the various pillars so that they will resist flexing or bending. Thereafter, the ends of the optical fibers are ground to a final dimension and polished. If desired, the wax-like material may remain after the grinding and polishing operation provided it has an index of refraction which is less than that of pillar material. If desired the ends of the optical fibers can be shaped to form a convex lens by either heating or shaping during the molding process. If the lens is formed during the molding process, it can be either concave or convex.

Referring to FIG. 4, there is illustrated an enlarged cross section view through a row of pillars 48N, 50N and support member 42 of FIG. 3 when formed with Fotoform material. During the etching process, the acid solution first removes the material from the very ends of the fibers being formed. Thus, the acid solution is in contact with the ends of the fibers for a larger period of time then it is in contact with the base of the fibers coupled to the support member 42. As a result, the optical fibers become slightly tapered as illustrated in FIG. 4. In one embodiment, the dimension C, which is the center-to-center spacing of the optical fibers is 400 microns; the dimension d, which is the final face diameter of the optical fiber is 40 microns; the dimension m, which is the mask feature diameter is 100 microns; the dimension L, which is the stub length of the optical fiber length is 600 microns; and, the dimension t, which is the thickness of the support member, is 250 microns.

If it is assumed that, with Fotoform material, an area of 10 microns is needed for exposure to the UV light, then the closest center-to-center spacing of the optical fibers which can be obtained is $d+2L \tan (3°)+10$ microns which, for our device, is roughly 112 microns. The dimension of 3° in the relationship is the taper angle of the pillar.

In still another embodiment of the invention, where the pillars are formed using Fotoform, a layer of etch resistance glass is positioned between two layers of Fotoform. The etch resistant glass can have a thickness of 250 microns and each sheet of Fotoform can have a thickness of 600 microns. Thermal bonding or an adhesive of epoxy or the like can be used to attach the two sheets of Fotoform to the etch resistant glass. The sandwich assemblage is then exposed to UV light, heat treated and etched to form the inventive structure. As noted above, structural support material such as wax or the like can be poured into the spaces between the optical fibers and allowed to harden to prevent the various optical fibers from bending or flexing during subsequent grinding and polishing steps.

The inventive device disclosed is a simple to construct, zero-assembly, two dimensional optical fiber array connect device. In one embodiment, it is a single piece of glass or plastic in which multimode optical

with reference to Figures 4A-4C, Hawkins et al.'890 discloses a method for forming cylindrical lens arrays for solid state imager. In col. 6, lines 8-10, Hawkin discloses that it is known to have utilized the chemical mechanical polishing to selectively remove material from a surface of the workpiece. The inherent advantage of chemical mechanical polishing is to provide control over the polishing rate by regulating polishing pad pressure, downward forces, and the amount of slurry.

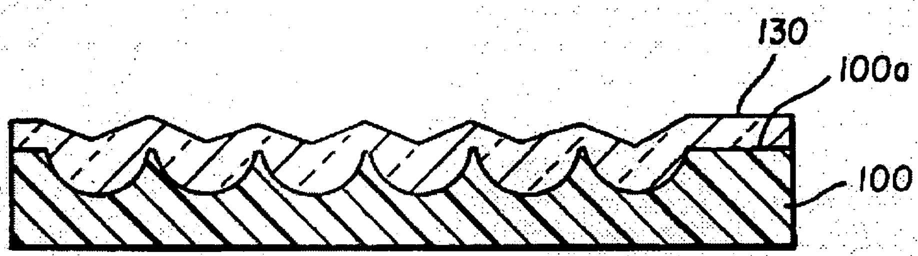


FIG. 4D

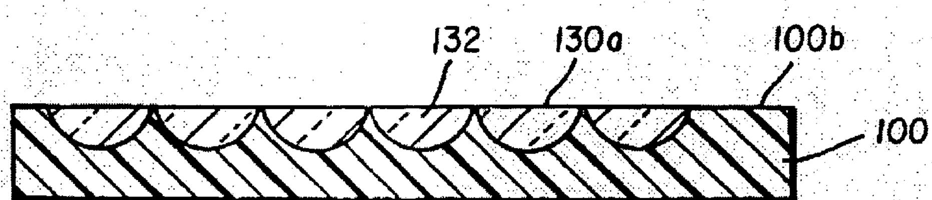


FIG. 4E

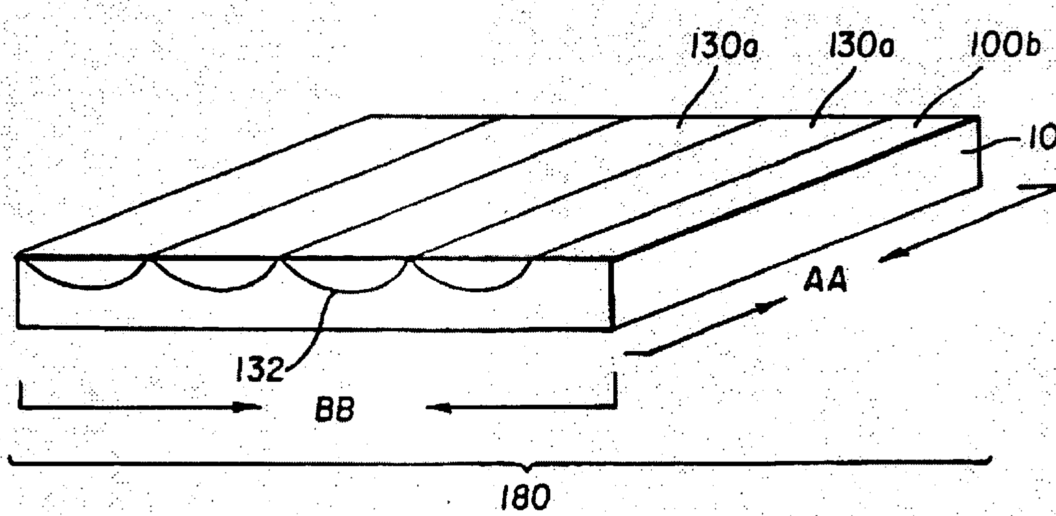


FIG. 4F

FIGS. 6A–6H are schematic cross-sectional views of a solid state imager made in accordance with this invention in which very narrow gaps are present between the convex cylindrical lenses; and

FIGS. 7A and 7B are schematic cross-sectional views of a solid state imager made in accordance with this invention in which a color filter array comprised of color filter elements is provided directly on the planar array.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Where parts or elements correspond to FIG. 1, FIGS. 2A and 2B, and FIGS. 3A and 3B, the same numerals will be used. Referring to FIGS. 4A through 4F, a first embodiment of the present invention is shown in which the lenses are cylindrical and the top surface of each lens is optically planar so as to refract light rays at the top surface in the manner expected for an ideal, flat dielectric. The cylindrical lenses of this embodiment are substantially contiguous with one another. Referring to FIG. 4A, a schematic cross-sectional view of a semiconductor portion 40 of the solid state imager is shown. A transparent substantially inorganic support layer 100, preferably oxide, is deposited over the active semiconductor portion 40, which serves a similar function to lens supporting layer in FIG. 1, in order to provide a surface on which to subsequently form lenses. The surface of the transparent substantially inorganic support layer 100 is then planarized, preferably by chemical mechanical polishing, to form an optically flat surface 100a which does not refract light away from the semiconductor portion 40 other than in a manner expected of an ideal planar dielectric.

Referring again to FIG. 4A, an etch-stop layer 110, preferably nitride, is deposited on the optically flat surface 100a. A photoresist layer (not shown) is used to pattern isolated openings 114 in the etch-stop layer 110 (as shown in FIG. 4B) in registry with the semiconductor portion 40. The location of apertures 24 in semiconductor portion 40 is shown by the dotted lines in top view FIG. 4B. FIGS. 4A and 4B also show bridge sections 116 of the etch-stop layer 110, preferably defined in registry with the semiconductor portion 40 so that the spacing between adjacent bridge sections 116 is the same as the size of the corresponding pixel. Bridge sections 116 serve to anchor adjacent strips of the etch-stop layer 110 during subsequent etching of the transparent substantially inorganic support layer 100 when the etch-stop layer 110 is substantially undercut. Central regions 118 lie midway between isolated openings 114 and midway between bridge sections 116.

Referring now to FIG. 4C, which is a cross-section AA of FIG. 4B, the transparent substantially inorganic support layer 100 is then subjected to a substantially isotropic etch which may be wet or dry, to provide depressions 120. The depressions 120 are substantially contiguous, touching one another at the optically flat surface 100a raider central regions 118 of etch-stop layer 110. The depressions 120 will come close to touching, for example closer than a few percent of the size of the pixel, but may not quite touch under regions 119 (FIG. 4B) of the etch-stop layer 110 between horizontally adjacent bridge sections 116, the isotropic etch having been slightly retarded by the bridge sections 116.

Referring now to FIG. 4D, the etch-stop layer 110 is removed and a substantially inorganic lens material 130 is formed having a refractive index higher than that of the transparent substantially inorganic support layer 100. The substantially inorganic lens material 130 is preferably a transparent substantially inorganic material, and is preferably chosen from the group nitride, titanium oxide, and tantalum oxide and can be deposited by vacuum evaporation or by application and densification of sol-gels. The top of the coating of the substantially inorganic lens material 130 is irregularly formed at this stage. Referring to FIG. 4E, the substantially inorganic lens material 130 is then planarized optically flat, preferably by chemical mechanical polishing, to the extent that the substantially inorganic lens material 130 is removed from the optically flat surface 100a of the transparent substantially inorganic support layer 100 in regions where no depressions 120 were formed, thereby forming lenses 132 having optically flat lens surfaces 130a. The lenses 132 are inverted from the prior art lenses FIGS. 1, 2A and 2B because the topes of lenses 132 are flat. The lenses 132 also differ from prior art lenses of FIGS. 1, 2A and 2B because they have an optically flat surface. As shown in FIG. 4E, the original optically flat surface 100a may be replanarized by the chemical mechanical polishing to a slight extent, and a new optically flat surface 100b of the transparent substantially inorganic support layer 100 formed. The optically flat lens surfaces 130a of the lenses 132 lie coplanar with the optically flat surface 100b. When viewed from above, as shown in FIG. 4F, the inverted lenses 132 lie in a planar array 180 of half cylinders and are spatially substantially contiguous. The planar array 180 is shown having cross-section AA and cross-section BB.

Turning now to FIGS. 5A through 5D, a second embodiment of the present invention is shown which further includes an overlying array of convex cylindrical lenses disposed perpendicularly to the planar array 180 of inverted cylindrical lenses 132. The use of a single array of convex cylindrical lenses is well know in the art to be advantageous for imagers with photodiodes whose length and width differ substantially, as taught for example by Ishihara, U.S. Pat. No. 4,667,092. However, single arrays of cylindrical lenses have not found wide application in imagers with square pixels, especially for small pixels.

Therefore, in accordance with the second embodiment of the present invention, a second array of convex cylindrical lenses 220 is formed on top of the planar array 180 of inverted cylindrical lenses 132 (as shown in FIG. 5C). The direction of the convex cylindrical lenses 220 in the second array is substantially perpendicular to the direction of the inverted cylindrical lenses 132, that is, perpendicular to cross-section BB and along cross-section AA as shown in FIG. 4F. The convex cylindrical lenses 220 formed on top of planar array 180 are preferably made from either organic or inorganic materials and are formed by thermal deformation of patterned strips of these materials. A preferred inorganic material is a low melting glass with a glass transition temperature less than 500° C. A preferred organic material is comprised of a substantially transparent polymer, for example, a polymer selected from the group photoresist, polymethyl methacrylate, polyimide, and polycarbonate, as is well known in the art.

FIGS. 5A through 5C depict cross-section AA of the planar array 180. Referring to FIG. 5A, a low melting glass layer 200 is uniformly deposited on the planar array 180 of inverted cylindrical lenses 132. A conventional photoresist layer 210 is patterned over the glass layer 200 to form narrowly spaced strips 200a. As shown in FIG. 5B, the pattern is then transferred to the low melting glass layer 200 by etching, preferably reactive ion etching, and the photoresist layer 210 is removed. The low melting glass layer 200 is preferably an oxide glass or a sol gel with a glass transition

Thus, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the micromachining method of Goossen with a chemical mechanical polishing step as taught by Hawkins et al.'890 in order to provide control over the polishing rate by regulating polishing pad pressure, downward forces, and the amount of slurry to selectively remove the material from the surface

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to George Nguyen whose telephone number is 571-272-4491. The examiner can normally be reached on Monday-Friday/630AM-300PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Joseph Hail can be reached on 571-272-4485. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

George Nguyen
Primary Examiner

George Nguyen
Primary Examiner
Art Unit 3723

GN – September 20, 2005